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Railway applications - Rolling stock equipment - Shock and vibration tests

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IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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Railway applications - Rolling stock equipment - Shock and vibration tests

FOREWORD

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IEC 61373 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways. It is an International Standard.

This third edition cancels and replaces the second edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) consideration of specific *ASD* spectra from onboard measurements and certification limited to the specific case;
b) exclusion from the scope of applicability of traction motors and any substructure not equipped with electrical, electronic or pneumatic device;
c) clarification for order of testing and typical test sequence, taking into account the possibility of simultaneous multi-axis testing;

d) recommendation and guidance for removing resilient mounts of the equipment (if located between the equipment and the main structure) during the long-life test;

e) qualification of the fixture device used to attach the equipment to the test bench;

f) guidance for using a measuring point as a possibility to assess mechanical integrity;

g) change of the method to calculate the acceleration ratio which shall be applied to the functional ASD value to obtain the simulated long-life ASD value;

h) duration of long-life test can be set from 5 h to 100 h per axis, with corresponding acceleration ratio (default value) indicated in a table;

i) clarification of the concept of structural integrity;

j) description of test exemption cases, subassembly tests, and finite element analysis for structural parts of equipment (new Annex E);

k) the lowest frequency f_1 of ASD spectra of Category 1 and Category 2 is fixed at 5 Hz as a default value, and the lowest frequency f_1 of ASD spectra of Category 3 is fixed at 10 Hz as a default value;

l) update of ASD spectra for functional random vibration test: Table 1, Table 2, Table 3, Table 4, Table A.2 and Figure 6, Figure 7, Figure 8, Figure 10. This update was recommended in the Rail Safety and Standard Board research program document: “Vibration environment for rail vehicle mounted Equipment”;

m) new annex F dedicated on urban vehicle operating on pneumatic tyres.

The text of this International Standard is based on the following documents:

Draft	Report on voting
9/3266/FDIS	9/3321/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,

– withdrawn, or

– revised.

INTRODUCTION

This document covers the requirements for random vibration and shock testing items of pneumatic, electrical and electronic equipment or components (hereinafter only referred to as equipment) to be fitted on to railway vehicles. Random vibration and shock is the only method to be used for equipment or component approval.

The tests contained within this document are specifically aimed at demonstrating the ability of the equipment under test to withstand the type of environmental vibration conditions normally expected for railway vehicles. In order to achieve the best representation possible, the values quoted in this document have been derived from actual service measurements submitted by various contributing bodies from around the world.

This document is not intended to cover self-induced vibrations as these will be specific to particular applications.

Engineering judgement and experience are recommended in the execution and interpretation of this document.

This document is suitable for design and validation purposes; however, it does not exclude the use of other development tools (such as sine sweep), which can be used to ensure a predetermined degree of mechanical and operational confidence. The test levels to be applied to the equipment under test are dictated only by its location on the train (i.e. axle, bogie or body-mounted).

It should be noted that these tests can be performed on prototypes in order to gain design information about the product performance under random vibration. However, for test certification purposes, the tests are carried out on equipment taken from normal production.

The procedures and requirements defined in this document do not substitute or overrule any structural assessment required from other structural requirement standards. This document is not intended to be used as a proof of fatigue strength.

NOTE European Standards EN 12663 and EN 13749 are examples of such structural requirement standards.

1 Scope

This document specifies the requirements for testing items of equipment intended for use on railway vehicles which are subsequently subjected to vibrations and shock owing to the nature of railway operational environment. To gain assurance that the quality of the equipment is acceptable, it is exposed to tests of reasonable duration that simulate the service conditions seen throughout its expected life.

Simulated long-life testing can be achieved in a number of ways each having their associated advantages and disadvantages, the following being the most common:

a) amplification: where the amplitudes are increased and the time base decreased;

b) time compression: where the amplitude history is retained and the time base is decreased (increase of the frequency);

c) decimation: where time slices of the historical data are removed when the amplitudes are below a specified threshold value.

The amplification method as stated in item a) above, is used in this document and together with the publications referred to in Clause 2; it defines the default test procedure to be followed when vibration testing items for use on railway vehicles.

Whilst this document is primarily concerned with railway vehicles on fixed rail systems, its wider use is not precluded. For systems operating on pneumatic tyres, or other transportation systems such as trolleybuses, where the level of shock and vibration clearly differ from those obtained on fixed rail systems, specific test levels can be considered. In that case, the frequency spectra and the shock duration and amplitude are computed in compliance with the guidelines in Annex A.

Annex F provides the functional random vibration load that can be considered by the user for urban vehicles operating on pneumatic tyres.

This document applies to single axis testing. However, multi-axis testing is possible.

The anchoring bolts at the fixing point(s) of the equipment are not evaluated in this document.

This document is intended to evaluate equipment which is attached to the main structure of the vehicle (and components mounted thereon). It is not intended to test equipment which forms part of the main structure. Main structure in the sense of this document means car body, bogie and axle.

The following items are out of scope of this document:

– the traction motors for railway vehicles;

– any mechanical substructure not equipped with electrical, electronic or pneumatic component.

Additional or special vibration tests for some specific equipment are not specified in this document, for example:

a) equipment mounted on, or linked to, items which are known to produce defined frequency excitation;

b) equipment such as pantographs, shoegear, or suspension components which are known to be exposed to specific shock and vibration excitation;

c) equipment intended for use in special operational environments as specified by the customer;

d) transportation and handling tests.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-27, *Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock*

IEC 60068-2-47, *Environmental testing - Part 2-47: Test - Mounting of specimens for vibration, impact and similar dynamic tests*

IEC 60068-2-64:2008, *Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance*
IEC 60068-2-64:2008/AMD1:2019

ISO 3534-1, *Statistics - Vocabulary and symbols - Part 1: General statistical terms and terms used in probability*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60068-2-64, ISO 3534-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/
– ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
random vibration
vibration the instantaneous value of which cannot be precisely predicted for any given instant of time

3.1.2
Gaussian distribution
continuous distribution with probability density function equal to:

$$P_x(x) = \frac{1}{\sigma \sqrt{2 \times \pi}} \times e^{\frac{-(x-\bar{x})^2}{2 \times \sigma^2}}$$

where

σ is the standard deviation;

x is the instantaneous value;

$\bar{x}$ is the mean value of x.

Note 1 to entry: See Figure 1.

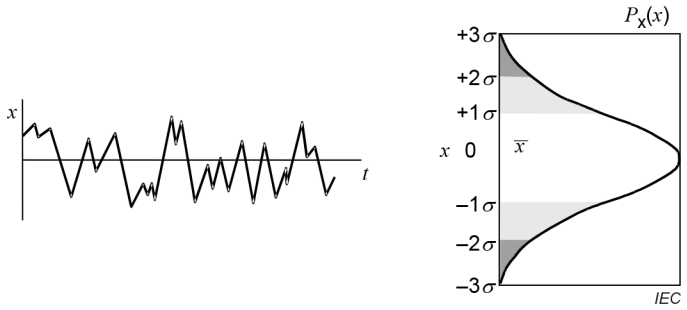

Figure 1 – Gaussian distribution

Note 2 to entry: According to Figure 1, the probability that the instantaneous acceleration value is between $\pm a$ is equal to the zone under the probability density curve $P_x(x)$. This means that the instantaneous acceleration value between:

– 0 and 1σ represents 68,26 % of the time,

– 1σ and 2σ represents 27,18 % of the time,

– 2σ and 3σ represents 4,30 % of the time.

3.1.3
acceleration spectral density
ASD
mean-square value of that part of an acceleration signal passed by a narrow-band filter of a centre frequency, per unit bandwidth, in the limit as the bandwidth approaches zero and the averaging time approaches infinity

3.1.4
component
<in a cubicle> pneumatic, electrical, or electronic part located inside a cubicle

3.1.5
cubicle
self-contained item of equipment, comprising structure, mechanical parts and mounted components

Note 1 to entry: Examples include converter, inverter, battery box.

3.1.6
anchoring bolt
bolt that enables the assembly of the equipment on the test table or the fixture device

3.1.7
internal bolt
bolt used in the equipment itself

3.1.8
acceleration ratio
coefficient applied to the functional ASD value to obtain the simulated long-life ASD value

3.1.9
weakest point
structural area which provides the lowest margin of safety under fatigue loads

3.2 Symbols and abbreviated terms

ADC	analog to digital converter
ASD	acceleration spectral density ((m/s^2)^2/Hz)
ASD_i	ASD value of the measured data number "i" ((m/s^2)^2/Hz)
DAT	digital audio tape
d_{LLT}	duration of the simulated long-life test (h)
DR	digital recorder
d_s	duration of the vehicle service life (h)
D_T	total cumulated damage of each element
D_{T_l}	cumulated damage of each element due to longitudinal acceleration
D_{T_t}	cumulated damage of each element due to transverse acceleration
D_{T_v}	cumulated damage of each element due to vertical acceleration
$D_{T_{ltv}}$	cumulated cumulative damage of each element due to longitudinal, transverse, and vertical acceleration (multidirectional load case)
D_M	cumulative admissible sum limit
d_X	projected longitudinal distance between the fixing point of the equipment and the validity plan (m)
E	Young's Modulus of material (MPa)
E_0	expected number of zero-crossings
E_P	expected number of peaks
f	frequency (Hz)
F	force (N) or (daN), should be consistent with other values
f_1	minimum frequency of ASD (Hz)
f_2	maximum frequency of ASD (Hz)
f_i	frequency value of the measured data number "i" (Hz)
FDS	fatigue damage spectrum
FTU	ultimate stress (or tensile stress) of material (MPa)
FEA	finite element analysis
FM	frequency modulation
H	transfer function
m	mass of the equipment (kg)
m_n	spectral moment rank n
n_c	number of check point(s)
N_S	the minimal number of cycles estimated during the service life
N_T	the minimal number of cycles estimated during the long-life test
PCM	pulse code modulation
PDF	probability density function
R	stress ratio (-)
RH	relative humidity (%)
RMS	root mean square value

RMS_i root mean square value of check point number "i"

R_p yield strength of material (MPa)

S_1 safety factor (-)

WB wheelbase of the bogie (m)

Δf frequency resolution of the ASD (Hz)

$\Delta\sigma_L$ fully reversed cut-off limit of material (MPa)

$\Delta\sigma_{RMS_i}$ RMS stress range of the block i on the element under functional ASD load (MPa)

γ irregularity factor

$\mathcal{E}$ material strain (%)

ε_S statistical error

σ stress at the centre of gravity of the element (MPa)

σ_D endurance limit of the material (MPa)

σ_L cut-off limit of the material (MPa)

ζ damping ratio (-)

4 General

This document is intended to highlight any weakness which can result in problems as a consequence of operation under environments where vibration and shock are known to occur in service on a railway vehicle. This is not intended to represent a full life test. However, the test conditions are sufficient to provide some reasonable degree of confidence (depending on hypothesis of fatigue strength parameters) that the equipment will survive the specified lifetime under service conditions.

The test levels quoted in this document have been derived from environmental test data, as referred to in Annex A. This information was submitted by organizations responsible for collecting environmental vibration levels under service conditions.

The following tests are mandatory for compliance with this document:

Functional random test	The functional random test levels are the minimum test levels to be applied in order to demonstrate that the equipment under test is capable of functioning when subjected to conditions which are likely to occur in service, on railway vehicles. The degree of functioning shall be defined prior to tests beginning (see 6.4.2). The functional random test is not intended to be a full performance evaluation under simulated service conditions. Functional random testing requirements are detailed in Clause 8.
Simulated long-life test	This test is aimed at establishing the mechanical integrity of the equipment at increased service levels. It is not necessary to demonstrate ability to function under these conditions. Simulated long-life testing requirements are detailed in Clause 9.
Shock test	Shock test is aimed at simulating rare service events. It is not necessary to demonstrate functionality during this test. Shock test requirements are detailed in Clause 10.

The equipment shall comply with the acceptance criteria listed in Clause 12.

The test values quoted in this document have been divided into three categories dependent only upon the equipment's location within the vehicle (see Figure B.1 of Annex B).

Category 1: Body mounted

Class A: Cubicles, subassemblies, equipment and components mounted directly on or under the car body.

Class B: Anything mounted inside an equipment case which is in turn mounted directly on or under the car body.

Class B is used:

– when it is not clear where the equipment is to be located;
– when there is a direct mechanical link between the car body and the traction motors.

Category 2: Bogie mounted

Cubicles, subassemblies, equipment and components which shall be mounted on the bogie of a railway vehicle.

Category 3: Axle mounted

Subassemblies, equipment and components or assemblies which are to be mounted on the wheelset assembly of a railway vehicle.

In the case of equipment mounted on vehicles with one level of suspension such as wagons and trucks, axle mounted equipment are tested as category 3. For all other equipment, there is no pre-defined associated category.

For reason of simplification, metric units are considered through this document.